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Understanding port choice behaviour: A network perspective

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Abstract A novel Network-based Integrated Choice Evaluation (NICE) model is developed to enhance the multinomial logit preference (MNL) model that is widely employed in the existing port choice literature. The NICE model integrates the element of port service network with observational port attributes to identify important quality characteristics on which liner shipping companies base their port choices. An empirical study of the proposed model is conducted through the service schedules of three established liner shipping companies. Results show that port efficiency and scale economies are the more important dimensions influencing liner shipping companies' selection of major Asian ports. Nevertheless, it is important for a competitive port to balance its efforts among all the dimensions.

Keywords Network-connectivity index · NICE model · Port choice · Port competitiveness

1 Introduction

The container shipping industry has undergone some major progressions over the last two decades. Through alliances, mergers and acquisitions, liner shipping companies have established a global network for their service (Wang and Cullinane 2006a; Parola and Musso 2007). The globalization of service network not only enhances service to shippers, but also accumulates sufficient volume that allows liner shipping companies to deploy large vessels and increase their cost efficiency

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(Cullinane and Khanna 1999). Coupled with rapid infrastructural development in emerging economies and improvement in logistics systems which result in higher accessibility to ports, ports' hinterlands have expanded and some of which overlap. Consequently, liner shipping companies enjoy a wider choice of ports for both transshipment traffic as well as gateway traffic in their hub-and-spoke networks.

Although it may be argued that the deployment of large vessels limits the choice of ports to those with sufficiently deep draughts, an understanding of the actual port choice behavior of liner shipping companies remains to be a pertinent issue for at least three reasons. Firstly, Lirn et al. (2003) have noted that the increasing concentration within the liner shipping industry has heightened the potent impact of a move by a major port user on the port's container traffic. Thus, intense competitions among ports become inevitable as port operators seek to improve the attractiveness of their ports to protect their market shares. Secondly, the dynamics of port industry have demonstrated emerging opportunities for a port to attract new shipping lines and the risks of losing important customers when liner shipping companies rationalize their shipping schedules and adjust their shipping routes and port choices. Thirdly, many port operators are setting up joint ventures with major liner shipping companies to ensure long term commitment in port calls. The degrees of success for these ventures depend heavily on the fit between those services rendered by competing ports and needs of the liner shipping companies. Given these circumstances, Slack (1993), Notteboom and Winkelmans (2001) and many others have advocated that ports must understand and adapt themselves to meet the frequently changing demands of their customers.

There are a number of studies in the port literature that have attempted to elicit the diverse considerations when liner shipping companies choose their ports of call. Earlier studies, such as Slack (1985), D'Este and Meyric (1992) and Murphy and Daley (1994), rely on surveys to obtain information on factors affecting port choice. While these studies have helped to identify and rank factors that are important to liner shipping companies, how and to what extent the identified factors will affect port choice are unclear. An extension of this literature is the use of the Analytic Hierarchy Process (AHP) model to analyze survey data. Responses are prioritized in some manner so that weights can be attached to various factors affecting port choice (Song and Yeo 2004; Lirn et al. 2004). As Schoner and Wedley (1989) have pointed out, AHP relies on strong assumptions to generate weights on the various factors and rank reversals among ports may occur when any of the alternative port is added or deleted. More recently, Tiwari et al. (2003), Nir et al. (2003) and Malchow and Kanafani (2004) have employed the Multinomial Logit (MNL) model to estimate the effect of important factors on port choice. Specifically, Tiwari et al. (2003) have studied the port selection behavior in China by applying a set of shipper's survey data on the discrete choice model and concluded that distance and port congestions are primary factors influencing port choice. Nir et al. (2003) have utilized survey data on the revealed preference model and found proximity of port, recent use and port cost to be more important considerations as compared to competition, frequency, route, port facilities or service. Malchow and Kanafani (2004) have reported that inland distance and frequency of shipments are negatively correlated with the probability of a port-shipper combination being chosen. However, since the generalized discrete choice model is not developed with the port or transportation industry in mind, a drawback of the direct application of the MNL framework to model port choices in these studies is that the indispensable element of network is neglected. The service network structure, which is a key feature of the container port industry, arises from the main business of a port. The main business of a port, defined in Wang and Cullinane (2006b) as the facilitation of cargo transportation from point of supply to point of demand, also bestows a critical role upon the port network-connectivity that determines the competitiveness of a port to a large extent. Polo and Diaz (2006) have added that a port can enjoy high connectivity, provided it possesses the important qualities valued by liner shipping companies.

Against the above background, this paper contributes to the extant literature in its development of a port choice model customized to the international shipping industry through a network representation. The Network-based Integrated Choice Evaluation (NICE) model requires the development of a new connectivity index founded upon the concept of network accessibilities (Hansen 1959; Taylor et al. 2006) and the evaluation of key port operating dimensions derived from factor analysis (Lattin et al. 2003). The proposed model utilizes published schedules from liner shipping companies to establish the service network of ports and derive the associated port connectivity indices. With the network connectivity indices established, observational port attributes such as port charges, ship turnaround time, annual port calls, operation hours, water depth, trade volume and availability of inter-modal facilities are integrated for the assessment of port preferences. Factor analysis[1] is applied on the port attributes not only to establish the port choice model, but offers a simple means to identify key independent operating dimensions and consequently, for comparing the performances of multiple ports across the key operating dimensions. The NICE model is empirically determined by expressing the port connectivity index as a conditional MNL function of these mutually and preferentially-independent port operating dimensions that allows for an assessment of the marginal contributions of each dimension separately. A schematic describing the entire NICE modeling process with specific data requirements is shown in Fig. 1.

The NICE model presents several advantages over the contemporary approaches. First, the NICE model seeks to derive the relative contributions of various port qualities to a port's overall attractiveness from the exhibited port users' behaviors in the form of port service networks (which give each port its connectivity) instead of subjective survey data. Second, the adoption of a network perspective allows an explicit consideration of inter-port relationship. Inter-port relationship is an important facet because ports do not operate in isolation of one another in today's inter-dependent global market and container movements from an origin port to a destination port occur within the liner shipping company's hub-and-spoke network that links container ports around the globe (Min and Guo 2004). Third, the connectivity index within the NICE model can also be interpreted as a measure of the competitiveness of a port as a logistics hub for sea cargo since liner shipping companies are major users of port services and connectivity indices are derived directly from liner shipping companies' voyage services for movements of sea cargo. In view of these advantageous features, the NICE model is

[1] Lirn et al. (2003) have suggested that factor analysis would provide an alternative approach to narrow down the number of port attributes and improve the methodology of their paper.

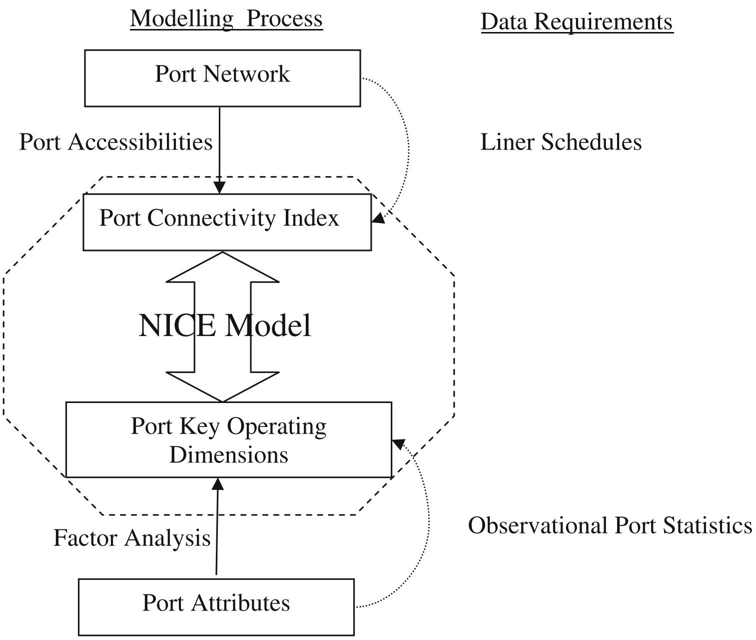


Fig. 1 Network-based Integrated Choice Evaluation (NICE) modeling process

useful for port operators to identify important quality characteristics on which liner shipping companies base their port choices. The identification of important port attributes would then provide port operators with key insights to improve their port infrastructure and operations.

The rest of this paper is organized in the following manner. “Section 2” builds the components required for the NICE model from a network perspective and describes the port attributes examined in the study. “Section 3” develops an empirical model in a case study which identifies important port attributes of major Asian ports. Ports are scored on the key operating dimensions, which are then reconciled with the proposed port connectivity index to empirically determine the NICE model. “Section 4” discusses the managerial implications of the resultant model. “Section 5” summarizes the main findings, suggests avenues for further research and concludes the study.

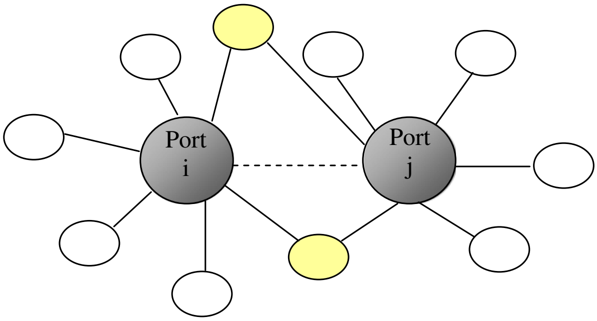
2 Model components

The development of the NICE model via a network perspective requires a network connectivity index. The construction of this index is discussed, followed by a listing of key port attributes employed in the identification of the independent dimensions influencing port choice via factor analysis.

2.1 Port connectivity index

Consider the simple network formed by two individual ports i and j as exemplified in Fig. 2. The linkage between port i and port j, represented by the dotted arc

Fig. 2 A representative network of port i and port j



between the two ports, suggests that each port will leverage on the network of the other port to expand its hinterland and serve a wider user base. Define two sets of origin-destination (O–D) pairs[2]—set A_i and set A_j such that A_i represents the set of O–D pairs that an individual port i serves and A_j represents the set of O–D pairs that an individual port j serves. It follows that the intersection of the two sets, $A_i \cap A_j$, represents the set of O–D pairs that both ports i and j will serve and the union, $A_i \cup A_j$, represents the set of O–D pairs that can be served using either port i or port j.

In order to compute the size of the sets defined above, let n_i and n_j be the number of exclusive nodes (including the port itself[3]) that can only be reached by port i and port j respectively. There is also some common nodes, denoted as n_{ij}, that can be reached by using either port i or port j. Hence, $n(A_i) = 2n_i n_{ij} + 2n_{ij} n_{ij}$ and $n(A_j) = 2n_j n_{ij} + 2n_{ij} n_{ij}$. Also, $n(A_i \cap A_j) = 2n_{ij} n_{ij}$ implies that we do not preclude the possibility of having an O–D pair between two identical common nodes via port i or port j. As opposed to $n(A_i \cap A_j) = 2n_{ij}(n_{ij} - 1)$, such inclusion of O–D pairs where the vessels begin and end at the same node is necessary to represent loop services.

Since $n(A_i \cup A_j) = n(A_i) + n(A_j) - n(A_i \cap A_j)$, the total number of O–D pairs that can be achieved with each port functioning independently can be computed as $n(A_i \cup A_j) = 2n_{ij}(n_i + n_j + n_{ij})$. Routes that require cooperation (i.e., connection) between port i and port j are those that start from an origin which has a single direct connection from port i to a destination that also has only a single direct connection from port j or vice versa. Hence, $n(A_i \otimes A_j) = 2n_i n_j$. Here $A_i \otimes A_j$ represents the set of O–D that are jointly served by ports i and j. As the sets $A_i \cup A_j$ and $A_i \otimes A_j$ are mutually independent, the total number of O–D pairs that will be served when both ports engage in cooperation can be obtained from $n\left(\left(A_i \cup A_j\right) \cup \left(A_i \otimes A_j\right)\right) = 2\left(n_j + n_{ij}\right)\left(n_j + n_{ij}\right)$.

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[2] By defining the set in terms origin–destination (O–D) pairs served by a port, our model is able to include transshipment routes in addition to direct shipping between point of supply and point of demand. If we define the sets as simply nodes served by a port, such treatment considers only the case of direct shipping (starting or ending at the port) and ignores the possibility of transshipment. Much of the existing port literature has documented that immense competitive pressure arises as each port seeks to attract transshipment traffic. The omission of transshipment route will lead to an under-estimation of the connectivity index, which can be easily verified through numerical computations.

[3] This extra node is needed to account for the possibility of a direct shipping route starting from a common node and ending at the port itself (or vice versa) without going further to other exclusive nodes from port.

According to Wang and Cullinane (2006b), ports constitute the nodes of a liner shipping network whereby liner shipping services provide the inter-port linkages that give each port its accessibility and potential for movements of cargoes. The accessibility of the port i is given by $\sum_j 2\left(n_i + n_{ij}\right)\left(n_j + n_{ij}\right)$, which can be viewed upon as a variation of the Hansen integral accessibility index described in Taylor et al. (2006). Taylor et al. also pointed out that such accessibility indexes are often used in normalized form. Hence we express the accessibility or connectivity index of port i, S_i, as a fraction of the number of O–D pairs served by port i to the total number of routes served by ports in the region. That is, $S_i = \frac{\sum_j 2\left(n_i+n_{ij}\right)\left(n_j+n_{ij}\right)}{\sum_j \sum_i 2\left(n_i+n_{ij}\right)\left(n_j+n_{ij}\right)}$. Here, the frequency variable is omitted for two reasons, namely, (1) to simplify the formulation for connectivity index, and, (2) to model the port choice behavior of the liner shipping company for a particular voyage, given the existing port service frequencies by other liner shipping companies and other important port attributes. Assuming that a voyage of the same itinerary is unlikely to repeat itself during a reasonably short time frame, the frequency may be implicitly taken into account as it will be counted η times in the computation of the connectivity index if the same port is selected in η different voyages sailed by a liner shipping company within a stipulated time frame.

2.2 Key port attributes

The key port attributes x_i examined in this study are: (1) number of port calls; (2) draught; (3) trade volume; (4) port cargo traffic; (5) ship turnaround time; (6) annual operating hours; (7) port charges; (8) availability of inter-modal transports.

The number of port calls (x_1) is a central consideration for liner shipping companies when selecting their stopover ports. A larger number of existing port calls implies a higher traffic that these companies can potentially intercept and also a shorter connecting time required to connect to vessels that lead to their destinations (Slack 1985; Tiwari et al. 2003). Hence, a virtuous cycle is effected as frequent port calls attract more liner shipping companies to stopover at the port, adding on to the number of port calls.

For reasons owing to scale economies, there is a trend towards the deployment of bigger vessels (Gilman and Williams 1976; Gilman 1999). The maximum vessel size which is able to berth at a port is determined by the water depth of a port (Baird 1996). The water depth, also known as draught (x_2), is an aspect that is significantly attributed to the geographical location of a port. While dredging efforts can increase water depth, such projects are very costly.

The trade volume (x_3) in a country is derived from two main sources, local consumptions and supply (i.e., imports and exports) as well as transshipment traffic. Generally speaking, economies that are more affluent or situated favorably near axes of major trading routes engage in more trade which translates into higher throughput at their major ports. As the maritime industry is characterized economies of scale in which large volume spreads out fixed cost and increases profits, volume is one of the factors that liner shipping companies will consider when deciding whether or not to call upon a particular port (Song and Yeo 2004). Nonetheless, trade volume represents an external factor beyond the immediate control of port operators.

Port cargo traffic (x_4) refers to the volume of cargo that goes through a port, including transshipment traffic. In Blonigen and Wilson (2006), volumes through ports are used to reflect aggregate individual port choice. We adopt TEUs as the basis of measurement for cargo traffic since TEUs is also the standard container size used for denoting the container carrying capacity for container ships.

Ports of higher efficiency are more likely to be chosen as stopover points by liner shipping companies because the loading and unloading rates of a port are analogous to speed of movements for a liner shipping company (Talley 2006). Efficient ports are characterized by short ship turnaround time (x_5) that is, in turn, controlled by other factors such as the availability of up-to-date physical facilities, labor productivity, speediness in custom services etc. Although modernized and more productive ports may charge higher port dues per ship hour, the improved speed reduces cost per cargo unit (Sanchez et al. 2003).

Some ports operate on a 24-h round-the-clock basis to reduce unproductive waiting time for the anchoring and unloading of vessels. The same goes for ports which operate whole year round, including national public holidays. In their survey, Murphy and Daley (1994) have revealed that convenient time ranked above 40 percentile among other important criteria when a liner shipping company selects its port of call. Our study computes the total annual operating hours (x_6) by multiplying the daily operating hours and the annual number of working days of the port.

Port charges represent the monetary cost of using the port. The importance of port charges in influencing port choice has been controversial with some past studies suggesting that service is a more important consideration (Tongzon 1995). Port charges can be classified into several categories such as charges on vessels, charges on containers and service charges. The average port charge per vessel (x_7), taken to be the terminal handling charge, is used as an estimation for port charges in this study. Since terminal handling charges refer only to the on-shore costs of using the container terminals, they are invariant to other attributes such as haulage distance, inland transport services and types of commodity being shipped.

The availability of intermodal transport facilities (x_8) in ports eases the handling of containerized imports and exports. Walter and Poist (2003) have exemplified that the provision of an intermodal transport transfer facility would permit containers to be off-loaded from railcars and then onto trucks for local and regional delivery easily. The empty containers could next be reloaded with locally manufactured and transshipment products bounded for exports. Hayuth (1991) believes that under one bill of lading for a door-to-door delivery for which a single company is responsible to design the entire trip, a company may select a port, not on the basis of its performances, reputations, or cost of services, but on the results of a comprehensive analysis of the total route that necessitate the need for greater coordination between sea, land and even air transport. For simplicity, we use a binary variable (0, 1) to denote the presence of rail and airport facilities since their distances from port is not available for all the observations in the sample.

3 Case study

The empirical analysis utilizes the service schedules published by three major liner shipping companies. Out of these three companies, Company A and Company B operate outside an alliance structure. As such, they are able to pursue a strategic approach that focuses on organizational flexibility, market responsiveness and decision-making independence in the design of their shipping service networks (Parola and Musso 2007). On the other hand, Company C engages in strategic alliances which bring many benefits to the company. These benefits include economies of scale (i.e., the ability to operate bigger vessels), operational synergies (i.e., the ability to achieve a better allocation of vessels) and market control (i.e., the ability to increase market power). Regardless of the specifics of their strategic inclinations, the superior performances of these liner shipping companies suggested that their service network selections accurately reflected the 'value' of the ports under the intense competition.

3.1 Port connectivity indices

The sample consists of 14 major Asian ports, including Singapore, Hong Kong, Kaohsiung, Shanghai, Busan, Incheon, Port Klang, Tanjung Pelepas, Yokohama, Tokyo, Tanjung Priok, Bangkok, Laem Chabang and Jawaharlal Nehru (also known as Nhava Sheva port). The selections of ports are in accordance to Wang (2005) who has observed that the mainline hub-feeder structure has focused large flows of containers and shipping capacity onto a small number of efficient ports that emerged as major ports for their countries or regions. Combined with the enhanced throughput capacity of these ports, these ports will attain significance at both the regional and global scale.

Figure 3 below presents the direct bilateral connectivity among the 14 major Asian ports in the partial shipping networks of the three liner shipping companies in June 2007. The dotted links are those ply by any one of the three liner shipping companies, whereas solid links are those which are ply by all the three liner shipping companies.

The number of O–D pairs[4] served by the ports and their associated connectivity indices in the service networks of liner shipping companies A, B and C are computed in Table 1 below. The figures in the parenthesis are the more conservative estimates in that they only consider network links which are present in all the three liner shipping companies.

3.2 Key port operating dimensions

This sub-section explores the pair-wise interactions between different port attributes (listed in "Section 2.2") and classifies the attributes into some broad, mutually and preferentially-independent dimensions using factor analysis. Ports are then scored according to their performances on the identified dimensions. From the data

[4] As an illustration, in the consolidated network depicted in Fig. 3, the Singapore and Hong Kong ports serve seven and three destinations respectively. Of these destinations, China is a common destination. (i.e., $n_{SIN,HKG} = 1$). It follows that, including the port itself, $n_{SIN} = 7$and $n_{HKG} = 3$. Using the formulas in "Section 2.1", a total of 48 O–D pairs are obtained.

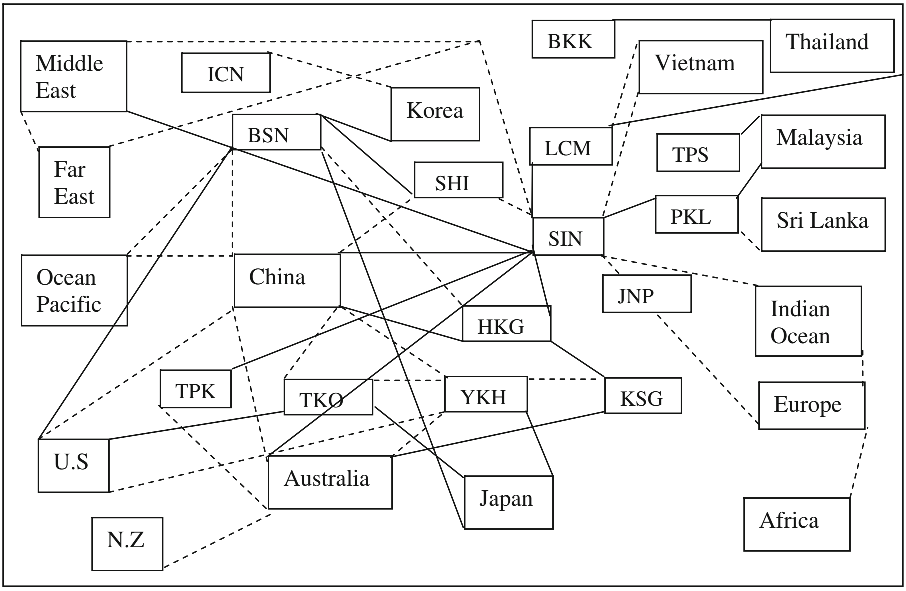

Fig. 3 Partial liner shipping networks. Legend: *SIN*—Singapore; *HKG*—Hong Kong; *KSG*—Kaohsiung; *SHI*—Shanghai; *BSN*—Busan; *ICN*—Incheon; *PKL*—Port Klang; *TPS*—Tanjung Pelepas; *YKH*—Yokohama; *TKO*—Tokyo; *TPK*—Tanjung Priok; *BKK*—Bangkok; *LCM*—Laem Chabang; *JNP*—Jawaharlal Nehru Port

provided in "Appendix", the correlation coefficients among the port attributes and the associated p values are displayed in Table 2.

With reference to Table 2, there appears to be sufficient evidences to reject the proposition that the number of port calls is unrelated to the port traffic from the high positive correlation of $\rho = 0.821$ in cell a. Similarly, the presence of a deep draught is one of the major considerations when liner shipping companies select their ports of call (with $\rho = 0.533$ in cell b). However, the total annual operating hours of a port bear no significant relationship with the number of calls the port enjoyed ($\rho = 0.363$ is insignificant in cell c) and there is also insufficient evidences to conclude that the mere availability of intermodal transport facilities has an impact[5] on the number of port calls ($\rho = -0.031$ is insignificant in cell d). With regard to the impact of service on port calls, ports with longer ship turnaround time attract smaller numbers of port calls as indicated by the correlation coefficient of $\rho = -0.422$ in cell e. According to Tongzon (1995), port charges generally form a negligible portion of the total logistics cost and are hence expected to have insignificant effects on traffic volume ($\rho = -0.032$) and number of port calls ($\rho = 0.101$) in cells f and g respectively. Conversely, the statistical correlations suggest that ports in countries engaging in high trade volume[6] are able to charge higher port dues ($\rho = 0.796$ in cell h).

[5] The proximity of these supporting infrastructures (not included in this study) could be more important.

[6] The total trade volume in a country comes from domestic imports and exports as well as transshipment. Ports located in centrality serve rich hinterland and benefit from larger domestic trade volume while those located in intermediacy at the intersection of major trading axes are able to capture additional transit cargo traffic to augment existing volume in home country.

Table 1 Number of O–D pairs served by selected ports and their connectivity indices

Region	Singapore	Hong Kong	Taiwan	South Korea	China	Japan		Malaysia	Indonesia	Thailand	India
Port	SGP	HKG	KSG	BUS	SHI	TKO	YKH	PKL	TPK	LCM	JNP
SGP	–										
HKG	416 312 144 (48)	–									
KSG	336 364 224 (36)	64 234 96 (36)	–								
BUS	448 252 210 (88)	160 154 98 (56)	96 364 176 (30)	–							
SHI	224 160 66 (28)	80 130 42 (12)	48 80 30 (20)	64 60 60 (24)	–						
TKO	336 988 78 (36)	120 112 42 (20)	72 338 144 (18)	96 40 24 (8)	48 50 36 (16)	–					
YKH	448 68 96 (16)	160 48 48 (8)	96 338 96 (24)	128 28 56 (6)	64 50 18 (12)	96 32 18 (4)	–				
PKL	112 176 154 (36)	80 224 98 (12)	48 208 126 (20)	64 176 140 (8)	32 144 112 (16)	48 160 84 (16)	64 160 70 (12)	–			
TPK	224 72 48 (12)	80 66 24 (8)	72 84 32 (8)	96 36 36 (10)	48 60 30 (12)	72 42 20 (6)	96 30 24 (4)	48 144 98 (12)	–		
LCM	224 132 48 (16)	120 144 16 (4)	48 132 24 (8)	64 132 36 (10)	32 90 18 (12)	48 120 20 (6)	64 96 16 (4)	48 110 70 (4)	72 60 8 (4)	–	
JNP	112 60 22 (16)	80 56 14 (8)	24 60 18 (8)	32 36 16 (6)	16 28 8(6)	24 24 8 (6)	32 16 10 (4)	80 32 12 (6)	48 20 6 (4)	48 32 6 (4)	–
Total number of O–D pairs	2,880 2,584 1,090 (332)	1,346 1,480 622 (212)	904 2,202 966 (208)	1,248 1,278 852 (246)	656 852 420 (158)	960 1,906 474 (136)	1,248 866 452 (94)	456 1,534 964 (142)	856 614 326 (80)	768 1,048 262 (72)	448 364 120 (68)
S_i	0.242 0.175 0.166 (0.190)	0.114 0.100 0.095 (0.121)	0.076 0.150 0.148 (0.119)	0.105 0.087 0.130 (0.141)	0.055 0.058 0.064 (0.090)	0.081 0.129 0.072 (0.078)	0.105 0.059 0.069 (0.054)	0.048 0.104 0.147 (0.081)	0.072 0.042 0.050 (0.046)	0.065 0.071 0.040 (0.041)	0.038 0.025 0.018 (0.039)

Combining the results, it may be inferred that ports serving affluent hinterlands and/or favorably situated near major trading axes can command higher port charges without hurting traffic. Meanwhile, ports that provide slower services are associated with lower port charges on the observation of $\rho = -0.676$ in cell i.

Table 2 Correlations among port's attributes

	Port traffic	Port calls	Annual operating hours	Draught	Intermodal transport availability	Trade	Ship turnaround time
Port calls	0.821 (0.000)[a] a	1.000					
Annual operating hours	0.312 (0.277)	0.363 (0.202) c	1.000				
Draught	0.507 (0.064)	0.533 (0.050) b	−0.202 (0.489)	1.000			
Intermodal transport availability	0.082 (0.782)	−0.031 (0.915) d	0.327 (0.253)	−0.174 (0.552)	1.000		
Trade volume	0.118 (0.688)	0.218 (0.454)	0.315 (0.273)	−0.079 (0.787)	−0.229 (0.431)	1.000	
Ship turnaround time	−0.220 (0.492)	−0.492 (0.094) e	−0.234 (0.464)	−0.359 (0.252)	0.401 (0.196)	−0.322 (0.307)	1.000
Port charges	−0.032 (0.921) f	0.101 (0.755) g	0.284 (0.372)	0.078 (0.810)	−0.302 (0.340)	0.796 (0.002) h	−0.676 (0.010) i

[a] Figures in parentheses refer to the *p* values

Normalizing the port variables[7] in "Appendix" and applying factor analysis, we obtain the factor loadings in Table 3. Using Varimax rotation, three variables (i.e., trade volume, turnaround time and port charges) load heavily on factor 1. Thus, factor 1 relates to the efficiency of the port. The port traffic, number of port calls and draught variables load on factor 2, so factor 2 is termed the scale economies offered by the port. The rest of the variables, namely annual operating hours of port and the availability of intermodal transport facilities, load on factor 3 indicating that factor 3 conveys the convenience in using the port.

In order to determine the location of each of the original observations in the reduced factor space, we compute the factor scores[8] from the factor score coefficients in Table 4. The factor scores computed are shown in Table 5.

To aid visibility, Fig. 4(a)–(c) below plot the relative positions of the ports along the three dimensions. From Fig. 4(a), we observe that the ports of Hong Kong and Singapore offer the greatest scale economies while the Japanese ports (Tokyo and Yokohama) are superior performers in efficiency. Figure 4(b) shows that although smaller ports like Bangkok, Tanjung Priok and Klang are comparatively less

[7] Normalization is done such that the best performing port in the category is given the highest score of ten points. For example, the port with the deepest draught will score 10. The score for other ports are computed using the formula: (Depth of draught at port) divide by (Deepest draught of ports in sample) and multiply by 10. When dealing with ship turnaround time and port charges, a little more care is required to retain such scoring scheme. Ports with the lowest figures will be given the highest score of 10 and other ports are scored against the benchmark set by the best performing ports. In this way, we prevent the offsetting effect which will otherwise occur (for example, long turnaround time versus low port charges)

[8] The factor scores for each individual port in Table 5 are estimated from $[\xi_1\ \xi_2\ ...\ \xi_c] = \mathbf{X}\mathbf{R}^{-1}\ \mathbf{A}_c$ where $\mathbf{R}$ is the sample correlation matrix.

Table 3 Factor loadings and communalities (unrotated and varimax rotation)

Variable x_i	Factor 1	Factor 2	Factor 3	Communality
Port traffic (TEUs)	0.663, 0.090	0.602, −0.864	0.120, −0.264	0.825, 0.825
Port calls	0.792, 0.246	0.517, −0.892	0.053, −0.199	0.896, 0.896
Annual operating hours	0.491, 0.416	−0.037, −0.174	0.763, −0.787	0.823, 0.823
Draught	0.453, −0.049	0.540, −0.793	−0.592, 0.466	0.848, 0.848
Inter-modal transport	−0.202, −0.390	0.399, −0.036	0.727, −0.758	0.729, 0.729
Trade volume	0.612, 0.870	−0.611, 0.063	0.169, −0.129	0.777, 0.777
Ship turnaround time	0.882, 0.767	−0.177, −0.484	−0.152, 0.103	0.832, 0.832
Port charges	−0.801, −0.950	0.536, 0.154	0.063, −0.074	0.932, 0.932
Variance	3.348, 2.643	1.783, 2.465	1.534, 1.553	6.665, 6.662
% Var	41.541, 33.039	22.282, 30.869	19.174, 19.402	83.310, 83.310

The first and second values are obtained without and with rotation. For standardized variables X, the square of the correlation coefficient, , known as the communality of x_i gives the proportion of variation in x_i accounted for by the common factor ξ. This common factor model, comprising eight variables and three common factors, can be written in matrix notation form as where $\mathbf{A_c}$ is a eight by three matrix of coefficients

efficient, these ports fare very well in the dimension of convenience by providing 24 h round-the-clock service and intermodal transport transfer facilities. Figure 4(c) compares port performances in terms of scale economies and conveniences offered by individual ports. Results from Fig. 4(a)–(c) imply that the Korean ports (Busan and Incheon) are well-balanced in all the three measures.

3.3 NICE model

Assuming that a liner shipping company will rationally choose the ports to stopover based on their perceived attractiveness in efficiency-related and scale-related cost advantages and conveniences, the port connectivity index (S_i) can be suitably expressed as a function of the mutually and preferentially-independent dimensions identified in "Section 3.2". Denoting port efficiency, scale economies and convenience as F_1, F_2 and F_3 respectively and standardizing the factor scores,[9] we obtain the logit model for port i as

$$S_i = \frac{e^{-0.0736+0.1571F_1+0.1162F_2+0.0370F_3}}{1+e^{-0.0736+0.15711F_1+0.1162F_2+0.0370F_3}} + \varepsilon_i$$

where ε_i is the error term

In a panel data consisting of 12 major Asian ports[10], this model provides a good fit between the connectivity index of a port and its performances on the three key operating dimensions. The R-square and adjusted R-square values associated with the model are 0.9193 and 0.8789 respectively and the model is overall significant with an F statistic of 22.769.

[9] While the main purpose of standardization (i.e., dividing the score in each observation by score of the best performer in the same dimension) is to avoid dominance of measures with bigger figures, we also convert the negative scores into positive ones for ease of interpretation.

[10] The Ports of Kaohsiung and Jawaharlal Nehru are omitted in the Multiple Logistic regression analysis due to the unavailability of information on the ship turnaround time.

Table 4 Factor score coefficients (unrotated and varimax rotation)

Variable	Factor 1	Factor 2	Factor 3
Port traffic (TEUs)	0.198, −0.079	−0.343, −0.368	−0.075, −0.143
Port calls	0.236, −0.017	−0.290, −0.362	−0.034, −0.098
Annual operating hours	0.147, 0.140	0.017, 0.000	−0.497, −0.499
Draught	0.135, −0.118	−0.303, −0.376	0.389, 0.325
Inter-modal transport	−0.060, −0.178	−0.227, −0.044	−0.472, −0.495
Trade volume	0.183, 0.370	0.342, 0.146	−0.113, −0.074
Ship turnaround time	0.263, 0.258	0.100, −0.119	0.100, 0.091
Port charges	−0.239, −0.377	−0.301, −0.053	−0.040, −0.065

The first and second values are obtained without and with rotation

The coefficients of all the three explanatory variables report the expected signs, with efficiency (ρ = 0.0008) and scale economies (ρ = 0.0032) being statistically significant at is α = 0.005. For a non-compensatory aggregation function, the coefficients of the independent dimensions are interpreted as the importance of the dimension in question relative to other dimensions in the model. As such, efficiency (whose coefficient is 0.1571) represents the most influential element which a successful port must be able to offer to its shippers. Scale economies, with coefficient 0.1162, is another critical dimension that a port would need to achieve to stay competitive. These together imply that favorable natural port conditions and conducive operating environments such as deep waters and large country trade volume are very important for ports to attract port calls. Convenience turns out to be less essential as Lee et al. (2008) have highlighted that inland transportation is not much of a concern to Asia ports. This is also congruent with our expectation since annual operating hours and intermodal transport availability are found to be statistically uncorrelated with port traffic earlier.

Table 5 Factor scores of selected ports (unrotated and varimax rotation)

Port	Factor 1	Factor 2	Factor 3
Hong Kong	0.1432, 0.8454	−1.0260, −0.7534	−0.6614, −0.4813
Singapore	−0.0798, 0.8325	−1.2284, −1.0819	−0.8698, −0.6427
Shanghai	0.0217, 0.4758	−0.5632, −0.5491	−0.9954, −0.8845
Busan	−0.1000, 0.4924	−0.7721, −0.7246	−0.6180, −0.4723
Port Klang	−0.3941, 0.1337	−0.5387, −0.7766	−0.7835, −0.6631
Tanjung Pelepas	−0.3885, 0.0905	−0.5174, −0.6981	−0.3982, −0.2875
Tanjung Priok	−0.2559, 0.1764	−0.4450, −0.6201	−0.8114, −0.7120
Laem Chabang	−0.1906, 0.1791	−0.4685, −0.4844	−0.1005, −0.0110
Tokyo	0.3984, 0.6697	−0.4679, −0.1869	−0.7312, −0.6553
Yokohama	0.5254, 0.7062	−0.4216, −0.0206	−0.4201, −0.3625
Bangkok	−0.1804, 0.1685	−0.3481, −0.5000	−0.8176, −0.7377
Incheon	−0.0586, 0.3244	−0.4855, −0.4732	−0.5210, −0.4273
Mean	−0.0466, 0.4246	−0.6069, −0.5724	−0.6440, 0.5281
Median	−0.0899, 0.4001	−0.5015, −0.5846	−0.6963, 0.5620
Standard deviation	0.2845, 0.2835	0.2671, 0.2783	0.2490, 0.2375

The first and second values are obtained without and with rotation

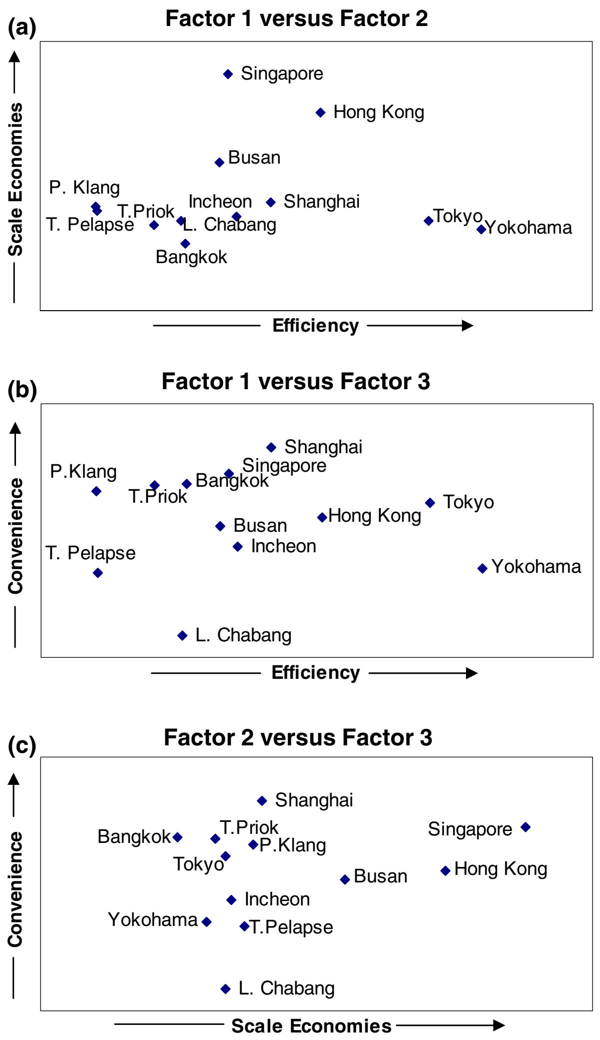

Fig. 4 (**a**) Relative port positions in the grid depicting factor 1 against factor 2; (**b**) Relative port positions in the grid depicting factor 1 against factor 3; (**c**) Relative port positions in the grid depicting factor 2 against factor 3

4 Discussions

Our study provides empirical accountability for the extraordinary traffic performance at some Asian ports. The Singapore and Hong Kong ports are able to attract liner shipping companies and achieve higher port connectivity owing to their fast ship turnaround time, impressive number of existing port calls and deep draught. Meanwhile, Shanghai port is driven by the enormous trade volume in its hinterland that enables the port to reap economies of scale and offset its disadvantage in shallow draught. Lower charges at ports do not seem to be able to compensate for longer ship turnaround time and stimulate traffic volume. The findings also reflect

Table 6 Transshipment traffic at selected ports (2004)

Port	Transshipment volume	Percentage of total throughput
Singapore	17,447,000	81.8
Hong Kong	6,661,000	30.3
Shanghai	6,244,000	42.9
Busan	4,754,000	41.6
Kaohsiung	5,070,000	52.2
Tanjung Pelapse	3,851,000	95.8
Port Klang	2,144,000	40.9
Kobe	326,550	15.0

Source: Containerization International

the contemporary trend towards increasing rationalization of shipping alliances that choose to call at fewer ports where efficient services are provided and scale economies can be achieved. As such, there is a pressing need for ports in ASEAN 4 (such as the Malaysian, Indonesian and Thailand ports) to increase port productivity to ensure long-term competitiveness and survival.

This study accounts for the location advantages of a port by taking into considerations the port traffic that arises, as a form of gravitational load, from the centrality and intermediacy of the port. According to Hayuth and Fleming (1994), centrality generates true O–D container traffic from and to the hinterland whereas intermediacy generates long-distance in-transit and transshipment traffic. Transshipment traffic is particularly important to ports facing small domestic demands, noting the significance of scale economies to liner shipping companies' port choice. Whereas, ports like Yokohama and Tokyo can acquire sufficient volume operating in an affluent country that engages in high volume of trade (a case of centrality), ports in smaller economies like Singapore could seek to attract transshipment traffic[11] through its intermediacy to augment the volume at port. Ports with high transshipment volumes are characterized by high connectivity since a liner shipping company will plan its schedule (i.e., the timing and frequencies of its stopover at a port) such that its vessels will be able to connect to the feeder services and capture the transshipment volume. For example, the Hong Kong port enjoys very frequent port calls from feeder vessels originating from or heading towards the vast mainland China. Table 6 below gives the transshipment share of the total traffic handled by some major ports in Asia. A simple Pearson correlation test confirms that the transshipment volume of a port is significantly related to the connectivity of a port with a Pearson correlation of 0.9616.

The strategic management literature in Porter (1980, p. 41) has advocated that a successful organization is one which chooses to excel on one critical dimension and avoid being "stuck-in-the-middle". On the contrary, results from our study reveal

[11] One of the most obvious factors determining a port's ability to attract transshipment traffic is the geographical location of the port. Ports located in proximity to major trading axes, such as Singapore, Hong Kong and Kaohsiung, attract transshipment traffic (Sutcliffe and Ratcliffe 1995). Physical location also affects connectivity through its impact on the marginal cost of stopping at a port. As an example, for a voyage originating from Singapore heading towards Yokohama, the Hong Kong and Shanghai ports present lower marginal cost compared to the Busan port.

that a successful port needs to be all-rounded in its service offerings even though port efficiency may be the most important consideration when liner shipping companies choose their ports of call. In other words, when ports are unable to outshine their competitors in all dimensions, ports should try to be a moderate performer in all aspects rather than concentrating all their efforts on just a single aspect and neglecting the others. As we have observed, the Japanese ports are highly efficient ports but they underperformed in terms of scale economies. Similarly, ASEAN 4 ports provide good convenience and charge low port dues but these ports are not able to attract high cargo traffic and port calls due to their lower efficiencies. On the other hand, Busan may not be the cheapest or most efficient port but its well-balanced service offerings have enabled it to achieve impressive traffic.

5 Conclusions

In this paper, we developed a novel Network-based Integrated Choice Evaluation (NICE) model that integrates the network characteristics of the port industry into the traditional multinomial logit preference model (MNL) via the connectivity index. The NICE model also takes into account the endogeneity of port variables and applies factor analysis on observational port attributes (such as port charges, turnaround time, annual operating hours, water depth and so forth) to derive port operating dimensions that are mutually and preferentially independent. Empirical results from the proposed model reveal that while port efficiency is most influential in increasing the attractiveness of ports, it is mandatory for a competitive port to perform reasonably well in scale economies and convenience.

Wilmsmeier et al. (2006) found that transportation costs only increase by 29.5% when distance doubles. Even in the face of rising oil prices, we recognized that fuel consumption depends upon other factors such as vessel type and consistency in vessel cruising speed rather than inter-port distance alone. Therefore, distances between ports were excluded from the set of port attributes and also in the subsequent set of key independent port operating dimensions. However, the accuracy of the relative importance of port dimensions established in this paper may be undermined by the omission of influential variables. For instance, container mix is a factor affecting the efficiency and hence connectivity of the port. Larger ports tends to handle a larger proportion of 40ft containers than their smaller counterparts but it takes approximately the same amount of time to handle containers of different sizes. Also, the hinterland trade structure (other than trade volume) can determine the need for space and other inputs. If there is a pronounced imbalance between the arrival and departure of cargo in the hinterland, there will be a need for large flows of empty containers that, in turn, adversely affect the productivity and efficiency of the port. Finally, port services should be measured in terms of reliability on top of ship turnaround time.

A natural extension of this study is to collect service network information from a variety of liner shipping companies for comparisons of port selection behavior among liner shipping companies of different sizes. Repeating the procedure over time will also lend insights into the potential changes in the playing field of the port industry and help port operators to devise future development plans for their ports.

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Appendix

Table 7 Port's attributes data of major Asian ports

	Traffic[a]	Connectivity[b]	Operations[c]	Maximum vessel size[a]	Inter-modal link[a]		Trade[c]	Efficiency[d]	Cost[d]
Port	TEUs ('000)	Port calls (per year)	Days, h (per year)	Draught (metres)	Airport	Rail	Volume (US$ b)	Turnaround time (days)	Port charges (USD)
Hong Kong	21,984	92,300	362, 24	15.50	1	0	525	2	210
Singapore	20,600	174,620	365, 24	15.00	1	1	332	2	117
Busan	11,430	83,547	351, 22	14.50	1	0	478	4	100
Incheon	935	47,600	351, 20	13.00	1	0	478	4	100
Shanghai	14,557	55,000	361, 24	9.50	1	1	952	7	110
Kaohsiung	9,710	36,500	353, 24	15.00	1	1	325	Unavailable data	
Port Klang	5,243	12,000	347, 24	13.40	1	1	213	7	65
Tanjung Pelepas	4,020	3,190	313, 08	14.40	1	1	213	6	85
Jawaharlal Nehru	2,370	Unavailable data	360, 24	12.00	1	1	166	Unavailable data	
Tanjung Priok	3,597	7,150	361, 24	10.60	1	1	115	5	92
Laem Chabang	3,529	4,650	349, 8.5	13.00	1	1	190	4	93
Bangkok	1,318	2,950	349, 24	8.50	1	1	190	4	93
Yokohama	2,717	42,200	344, 24	12.00	0	1	1,035	2	350
Tokyo	3,358	33,500	346, 24	13.00	1	1	1,035	2	350

[a] Source: Containerisation International Yearbook (2006)
[b] Source: Lloyd's Registered Fairplay (2007)
[c] Source: World Competitiveness Yearbook (2006)
[d] Source: Lee et al. (2006)

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